

CHAPTER 7
INTEGRATED HYDRAULIC AND ELECTRIC-BOOSTER BRAKE SYSTEMS

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CHAPTER 7

INTEGRATED HYDRAULIC AND ELECTRIC BOOSTER BRAKE SYSTEMS

1. SCOPE. This chapter applies to the operation and inspection of integrated hydraulic and electric-booster brake systems. Two similar systems are discussed, known in the automotive industry as the Hydro-Boost and Hydro-Max brake systems, respectively.

2. INTRODUCTION. The information in this chapter provides a general description of the operation of integrated hydraulic and electric-booster brake systems and their major component parts. It also provides an inspection procedure to determine whether the brake and hydraulic portion of such systems are functioning properly and component parts are adequately maintained. Definitions pertinent to this chapter are contained in Annex A.

3. SYSTEM DESCRIPTION AND OPERATION (INTEGRAL HYDRO-BOOST BRAKE SYSTEM).
 - a. System. A hydraulic brake system which uses hydraulic pressure developed by the motive power of the vehicle for the purpose of assisting a brake application is a "power brake" as defined in California Vehicle Code (VC) Section 480.

 - b. Description. One type of integral brake booster, commonly called the Hydro-Boost, consists of an open center spool valve and a hydraulic cylinder combined into a single housing. The booster utilizes hydraulic pressure supplied by a power steering pump or a separate brake pump to provide a power-assist to operate a dual master cylinder brake system. The Hydro-Boost unit reduces the pedal effort and the pedal travel required to apply the brakes. The amount of power-assist is regulated by the brake pedal application pressure.
 - (1) In some vehicle applications, the power steering pump provides the fluid pressure to operate both the hydraulically-powered integral brake booster (Hydro-Boost) and the power steering gear. In other vehicle applications, a dedicated power steering pump provides fluid pressure to operate only the power steering gear, while a separate pump provides fluid pressure to the Hydro-Boost unit.

 - (2) The Hydro-Boost also has a reserve power-assist system consisting of a compressed gas accumulator that stores sufficient gas under pressure to provide at least two assisted brake applications in the event that the fluid pressure from the power steering pump (or brake pump) is lost. With

considerably more driver effort, the brakes can also be applied manually (without power-assist) if the reserve system is depleted.

(3) Compared to conventional vacuum-assisted brake systems, the HydroBoost system delivers at least 30 percent more stopping power for heavily loaded trucks and buses. Additionally, brake performance is unaffected by mountain driving. Vacuum systems lose some of their power at high altitudes due to reduced atmosphere density.

(4) The integral Hydro-Boost brake system was developed for medium duty trucks and buses and is generally used in vehicles up to 46,000 lbs. gross vehicle weight rating (GVWR).

c. Operation - Brakes Released. Figure 7-1 illustrates the Hydro-Boost with brakes released (the master cylinder is not shown) and operates as follows:

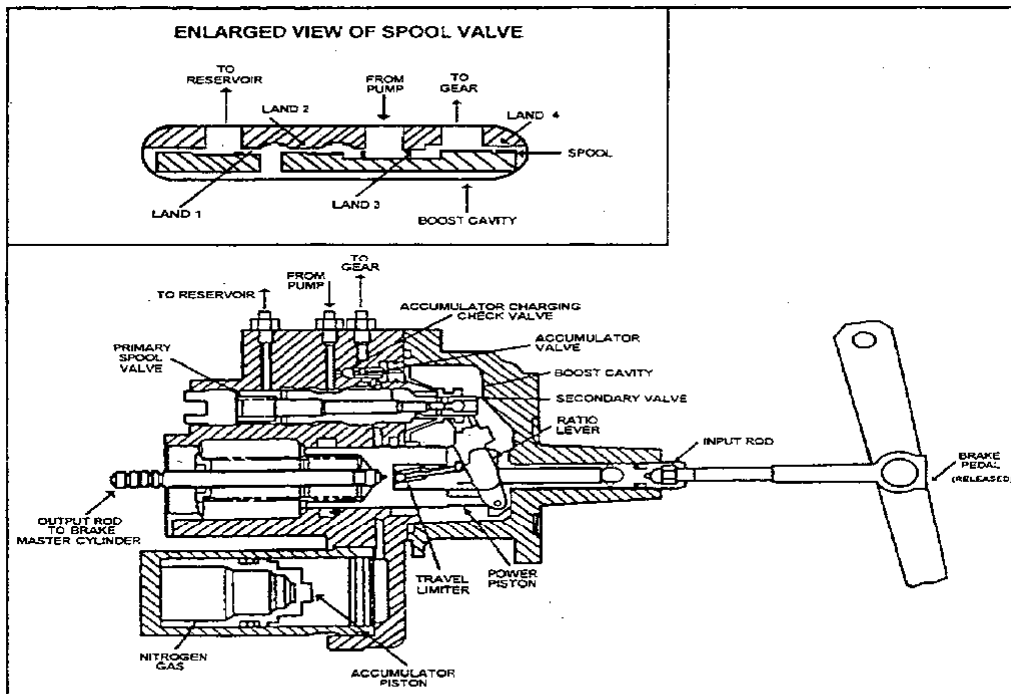


Fig. 7-1. Hydro-Boost - Brakes Released

(1) The forward end of the booster (left side of illustration) has a flange for attaching a master cylinder to the booster housing, and an output push rod projects from the booster cylinder bore. When the master cylinder is attached to the booster, the output push rod fits into the primary piston in the master cylinder bore.

NOTE: The term "forward" refers to the master cylinder end of the booster, and the term "rear" refers to the brake pedal end of the booster.

(2) The booster power section includes three ports as follows:

(a) Pressure Port. The high pressure line from the power steering or brake pump is connected to this port and provides the necessary pressure for the Hydro-Boost unit. This port is marked "from pump" at the top of the unit in Figure 7-1, just below the enlarged view of the spool valve.

(b) Gear Port. The high pressure line leading to the power steering gear is connected to this port which provides regulated hydraulic power assist for the steering gear. This port is marked "to gear" in Figure 7-1.

(c) Return Port. The return line to the power steering or brake pump reservoir is connected to this port which completes the system of fluid circulation. This port is marked "to reservoir" in Figure 7-1.

(3) The enlarged view of the spool valve illustrates the relationship of the valve's internal flow controls, called "lands," with the engine running and the brakes released. In this view, oil flows from the power steering pressure port, across the number 3 land and out the gear port, thus providing power steering assist.

(4) In the brakes released position, hydraulic pressure used by the steering gear and pump is isolated from the boost cavity by the position of the spool valve. With the spool valve in this position, lands number 2 and number 4 are blocked, thus preventing fluid pressure from entering the boost cavity. In this position, full fluid flow returns directly back to the reservoir.

d. Operation - Brakes Applied. Figure 7-2 illustrates the Hydro-Boost with the brakes applied (the master cylinder is not shown).. It operates as follows:

(1) As the brake pedal is applied, the input rod travels into the boost body, moving the ratio lever. The ratio lever operates the spool valve, which causes a variable force to be applied to the output rod that connects to the master cylinder.

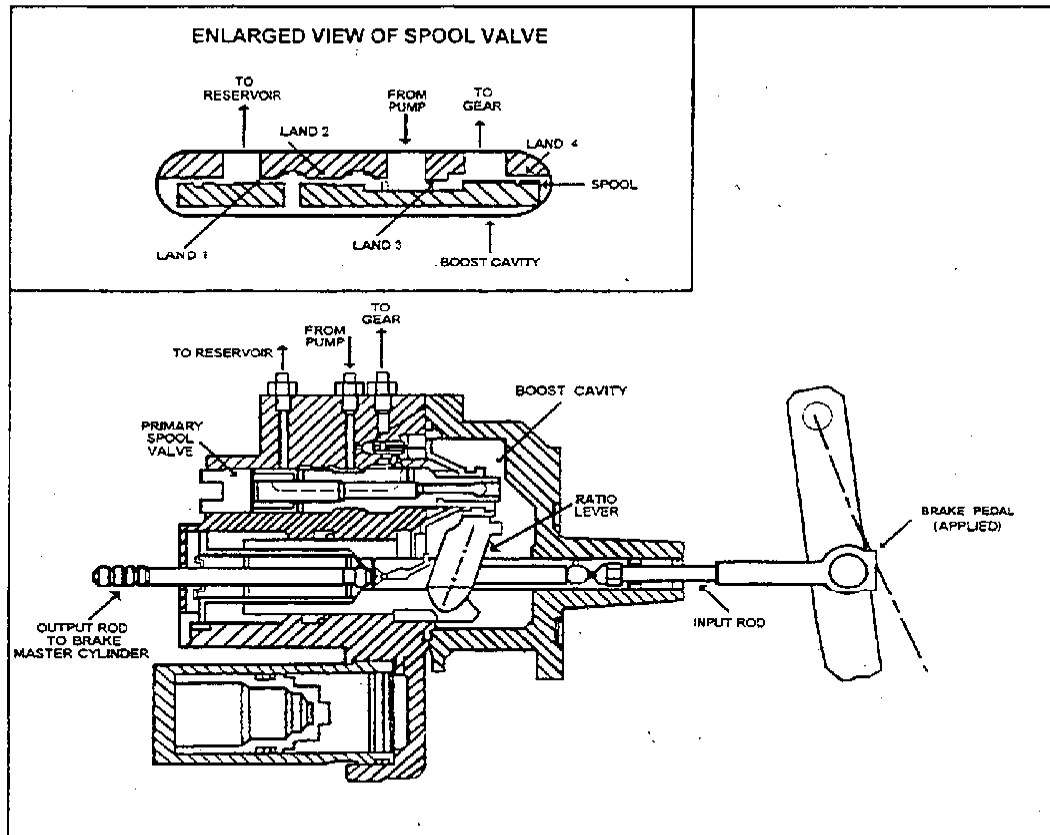


Fig. 7-2. Hydro-Boost - Brakes Applied

(2) Fluid flows through the center of the spool into the boost cavity. This pressure acts against the power piston to produce the power-assist effect, by adding fluid pressure to the driver's manual effort in applying the brakes.

(3) The enlarged view of the spool valve shows the relationship of the valve's internal flow controls, called "lands," during normal brake operation. In this view, land 1 is closed, which blocks the oil flow to the reservoir. Simultaneously, land 3 meters the flow of oil from the supply pump to the steering gear and land 2 meters the flow of oil to the brake booster piston. In this case, full flow is directed to the steering gear and to the brake booster (brakes applied).

(4) If, while braking, additional fluid pressure is required for steering movements, the increased demand for fluid volume will cause the spool valve to open further, which allows more fluid to flow to the steering gear_ Even

under extreme braking, the fluid flow to the steering gear is sufficient for steering the vehicle.

e. Reserve Power System. The Hydro-Boost reserve braking system illustrated in Figure 7-3 consists of a pressure accumulator, which uses three main parts: a compressed gas (nitrogen) accumulator; an accumulator charging check valve and an accumulator valve. The accumulator valve is actually an accumulator discharge valve, that is, it is the device that causes the accumulator to do its job when the hydraulic assist fails. The reserve power system operates as follows:

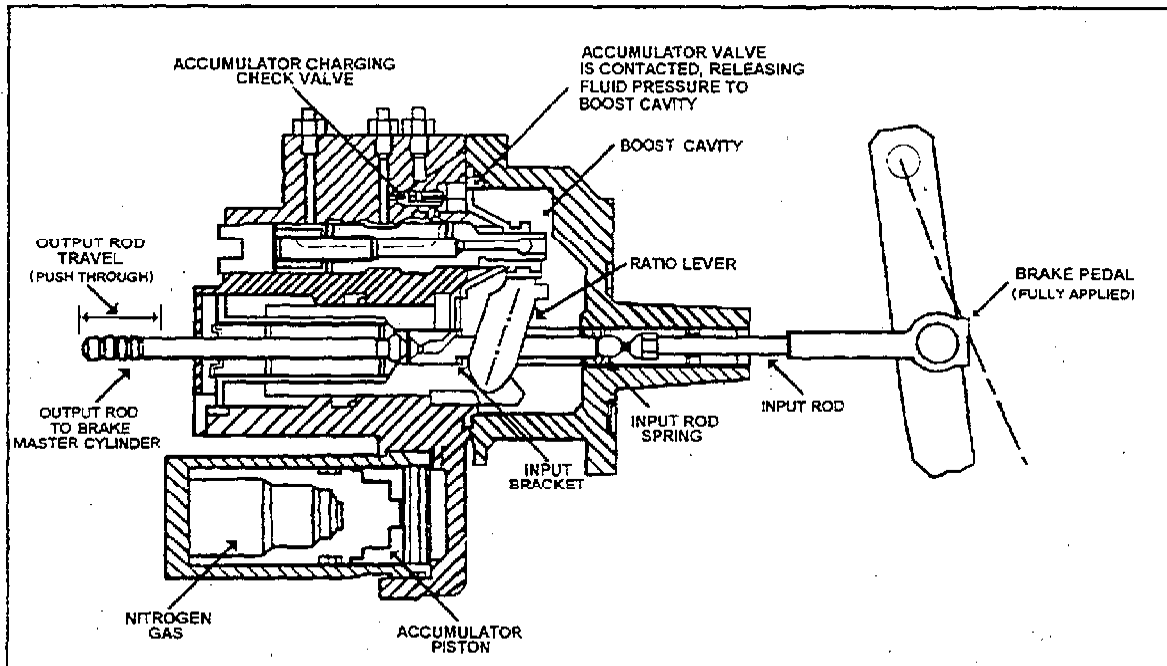


Fig. 7-3. Hydro-Boost - Reserve Power System

- (1) The system is open to the pressure port of the Hydro-Boost. The accumulator is charged by the pump pressure during normal operation through a check valve that communicates with the pump port.
- (2) The charging valve has an orifice and a check valve. Fluid from the pump passes around the check valve into the accumulator if the pump pressure exceeds the pressure in the accumulator. The charging rate is controlled by the orifice to minimize the effect on fluid flow to the steering gear. The check valve prevents reverse flow when pump pressure drops below accumulator pressure, as it would if the pump or its driving mechanism failed.

(3) The accumulator valve is a small poppet-type valve held closed by the pressure stored in the accumulator. An actuator on the spool valve sleeve opens the accumulator valve when a stop is made. It is this valve that delivers stored pressure from the accumulator to the booster unit under emergency conditions.

(4) Fluid pressure can also enter the accumulator from the boost chamber through the accumulator valve. This condition occurs whenever boost cavity pressure momentarily exceeds accumulator pressure, such as during the first few times the engine speed is increased above idle after the engine is started.

(5) A pressure relief valve vents the accumulator to the pump pressure port whenever pressure in the accumulator exceeds approximately 1,400 psi.

(6) When reserve power in the accumulator is depleted, further application of the brake pedal causes the input bracket to separate from a shoulder on the input rod and compresses the input spring, allowing a change of ratio between the input and output rods. This ratio increase will cause the brake pedal to travel further and increases the mechanical force applied to the master cylinder. This is referred to as "mechanical push-through capability." This push-through capability ensures that after the brake pump has failed and the accumulator has been depleted, it is still possible to apply the brakes manually. Much greater driver effort is required to apply the brakes in this manner, but in emergency situations drivers tend to apply maximum effort as a matter of reflex (or panic, in many cases). The push-through system is purely an emergency feature that provides greatly reduced braking power, and the vehicle should not be operated in this mode except for its emergency removal from the road.

4. COMPONENT PARTS (HYDRO-BOOST INTEGRAL BRAKE SYSTEM).

a. Master Cylinder Portion of a Hydro-Boost Brake System. In a Hydro-Boost power brake system, the power-assist portion of the system is a closed, circulating fluid system that has no hydraulic connection with the rest of the brake system. Rather, it has a mechanical connection at the interface between the booster unit and the brake master cylinder. The brake system itself is a closed, reciprocating fluid system, meaning its fluid moves back and forth between the master cylinder and the wheel cylinders. This portion of the Hydro-Boost brake system is essentially the same as a straight, unassisted brake system such as is discussed in Chapter 5 of this guide:

b. Power Steering or Brake Pump Portion of a Hydro-Boost Brake System. Power steering pumps are directly driven by the engine and are specially designed to

supply pressurized oil to the power steering gear and Hydro-Boost unit in most vehicles equipped with this type of power brake system. In other vehicles, the brake pump is also engine-driven and is designed to supply pressurized oil to the Hydro-Boost unit only. If the vehicle is equipped with power steering, the power steering pump supplies oil only to the power steering gear.

(1) Figure 7-4 illustrates a typical power steering system for a medium duty vehicle showing a single hydraulic pump that supplies both the steering and the brake systems.

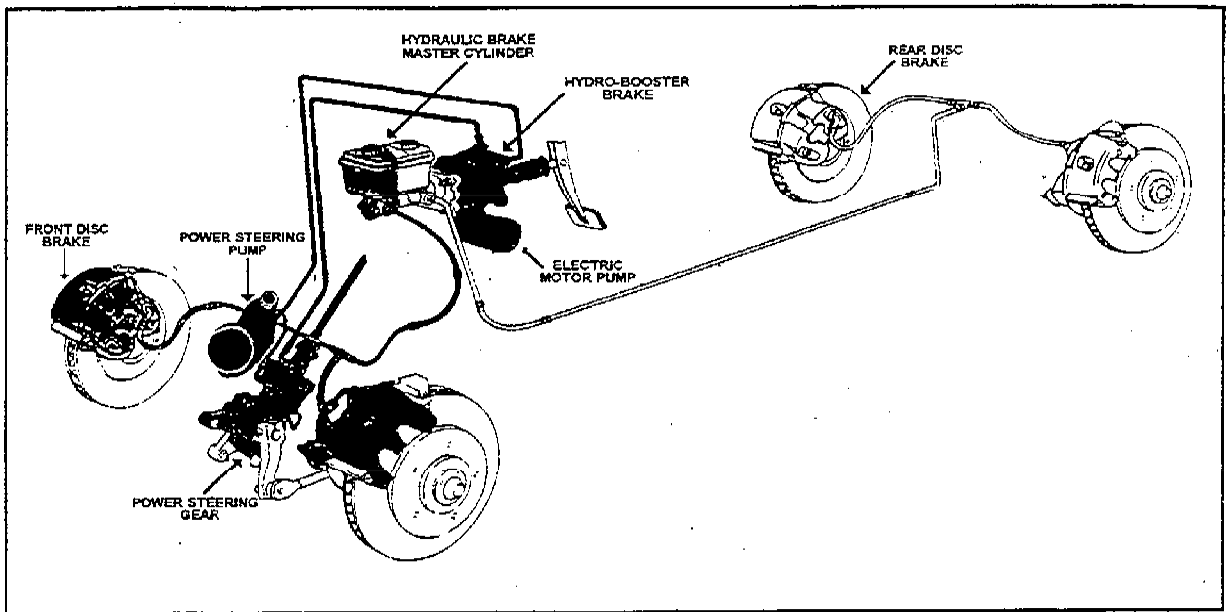


Fig. 7-4. Typical Power Steering System For Medium Duty Vehicle

(2) Figure 7-5 illustrates a typical medium duty vehicle with separate pumps for steering and brake systems.

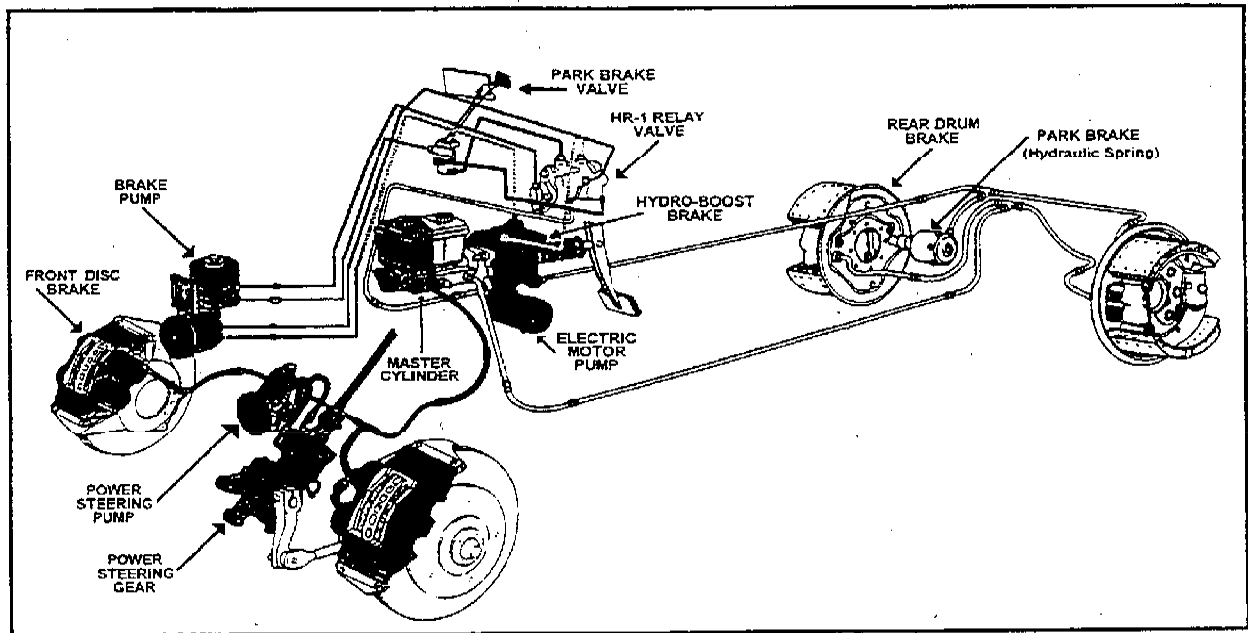


Fig. 7-5. Typical Brake Pump System For Medium Duty Vehicle

5. HYDRO-BOOST BRAKE AND STEERING SYSTEM FLUIDS.

a. The Hydro-Boost brake assembly is composed of the Hydro-Boost booster and a split-system brake master cylinder. These two devices operate with distinctly different and incompatible hydraulic fluids which must not be mixed. Persons who do not fully understand these systems sometimes think that by checking the fluid level of the HydroBoost system, they are checking the brake fluid level. In fact, the master cylinder could be empty while the hydraulic boost system is full.. The master cylinder fluid level must be checked separately. The booster system and the brake system are hydraulically isolated from one another, with only a mechanical connection between them at the master cylinder. For the clearest understanding of their hydraulic functions, it may be - helpful to think of the brake system and the booster system as unrelated.

(1) The Hydro-Boost booster (or brake pump) operates on power steering or automatic transmission fluid (whichever is recommended by the vehicle manufacturer), which are petroleum based hydraulic fluids.

(2) The brake master cylinder uses a glycol-based hydraulic brake fluid. The brake master cylinder should be filled only with brake fluid recommended by the vehicle manufacturer. Adding power steering fluid or automatic transmission fluid to a brake master cylinder could result in severe damage to the brake system seals and could result in a severe reduction of braking capability. Conversely, brake fluid must not be allowed to come in contact with internal parts of the Hydro-Boost.

6. INSPECTION PROCEDURES.

a. Preliminary Inspection. A preliminary visual inspection should include the following:

(1) Check to determine if the power steering or brake pump fluid level is within specifications, as indicated by markings on a dipstick, sight glass, or other measuring device on the vehicle designed for this purpose.

(2) Inspect the power steering or brake pump belt for tension, glazing, and cracks.

(3) Check the power steering or brake pump hoses and lines leading to or from the Hydro-Boost unit for leaks, kinking, chafing, or signs of "ballooning."

(4) Check the Hydro-Boost unit for power steering fluid leaks between the brake master cylinder and the Hydro-Boost unit, including leaks at the Hydro-Boost push-rod end located on the brake application pedal.

(5) Determine if the brake fluid level is within specifications and look for discoloration, cloudiness or "gumming" of the fluid in the brake master cylinder.

(6) Inspect the brake master cylinder for leaks at the hydraulic line connections and for brake hydraulic fluid leaks between the master cylinder and Hydro-Boost unit. Fluid leaks at the connection between the booster and master cylinder could be either brake fluid or power steering fluid.

b. Hydro-Boost Normal Noise Characteristics. The Hydro-Boost will emit normal minor hissing sounds when above normal brake pedal efforts (25 to 35 lbs.) are applied. The hissing sounds are particularly noticeable with the vehicle stopped, and will increase in intensity as brake pedal efforts increase or system operating temperatures increase. Power steering systems make similar sounds when the steering wheel is moved. These sounds are caused by the fluid(s) flowing through control valving inside high-pressure components. Minor clunk, chatter or clicking noises may be heard when the brake pedal is quickly released from hard pedal efforts.

NOTE: The amount of brake pedal effort is described as the foot pressure in pounds that is applied to the brake pedal when testing the basic functional operation of the Hydro-Boost and Hydro-Max brake systems as recommended by Allied Signal Bendix[®] Service Data publications.

c. Basic Functional Inspection. Check the brake and Hydro-Boost system as follows to determine if they function properly (Section 26453 VC).

(1) Brake Warning Light Test. While performing the test in paragraph (2) below, observe the brake warning indicator lamp, which must activate when the ignition (start) switch is in the "on" position. After the engine is started, and pump pressure has had a few seconds to generate, the brake warning lamp should not remain illuminated.

(2) Basic Hydro-Boost Test. With the parking brake released, and with the engine off, depress and release the brake pedal several times to deplete all hydraulic pressure from the Hydro-Boost. Depress and hold the brake pedal with light pressure (15-25 lbs.), then start the engine and run it at idle speed. If the Hydro-Boost is operating, the pedal will yield slightly to foot pressure, and then hold. Less pressure will be required to hold the pedal at this position.

(3) Brake Hydraulic Leak Test. Turn the engine off, depress and release the brake pedal several times, then hold the brake pedal down with medium pressure (25-35 lbs.). If the pedal gradually moves toward the floor while

being applied, the brake system could be leaking, and the master cylinder and brake system should be inspected as outlined in Chapter 5 of this guide.

(4) Hydro-Boost Leak Test. Start the engine and run it at idle speed. Apply the brakes with heavy pressure (100-125 lbs.) and hold while checking the Hydro-Boost for leaks. (Caution - do not hold the brake pedal at heavy pressure for more than five seconds at a time.)

7. SYSTEM DESCRIPTION AND OPERATION (INTEGRAL HYDRO-MAX BRAKE SYSTEM).

a. Description. Another type of integral brake booster is commonly called the Hydro-Max, and like the Hydro-Boost described above, it is a hydraulically operated brake booster powered by the power steering pump or a separate brake pump.

(1) The power steering pump provides the fluid pressure to operate both the,, hydraulically powered integral brake booster (Hydro-Max) and the power steering gear, unless a separate pump is provided. Like the Hydro-Boost, it also provides a variable power-assist that is regulated by brake pedal application pressure. The principal difference between the Hydro-Boost and Hydro-Max integral hydraulic brake boosters is the power source for the reserve braking function.

(2) As mentioned above, the Hydro-Boost has a compressed gas accumulator that stores nitrogen gas to provide at least two power-assist brake applications in the event that fluid flow from the power steering pump is lost. The Hydro-Max has an electrically operated pump that provides emergency powerassist to the brake system under the same circumstances.

(3) The electric-powered emergency pump of the Hydro-Max unit has an indefinite number of power-assisted stops available if the engine stalls, or if the power steering or brake pump system malfunctions. However, the electric motor supplies fluid at a somewhat lower pressure for power braking assist. Therefore, increased pedal effort is required to stop the vehicle, and the vehicle should not be operated in this mode except for its emergency removal from the road. Some of these systems have a buzzer that sounds whenever the brake pedal is pushed and the electric pump is the functioning source of power-assist. This signal emphasizes the emergency nature of the reserve power-assist feature.

(4) Like the Hydro-Boost, the Hydro-Max has a mechanical push-through capability if both of the other systems malfunction. The push-through system provides significantly reduced braking power requiring greater pedal

pressure, and the vehicle should not be operated in this mode except for emergency removal of the vehicle from the road.

b. Operation - Brakes Released. Figure 7-6 illustrates the Hydro-Max brake booster (with the master cylinder installed) with the brakes released. It operates as follows:

(1) With the engine running and the brakes released, oil pressure from the power steering or brake pump holds the Hydro-Max booster inlet check valve open. Before the brake pedal is applied, fluid passes freely through the pressure valve and into the low pressure chamber. From the low pressure chamber, fluid returns to the pump reservoir.

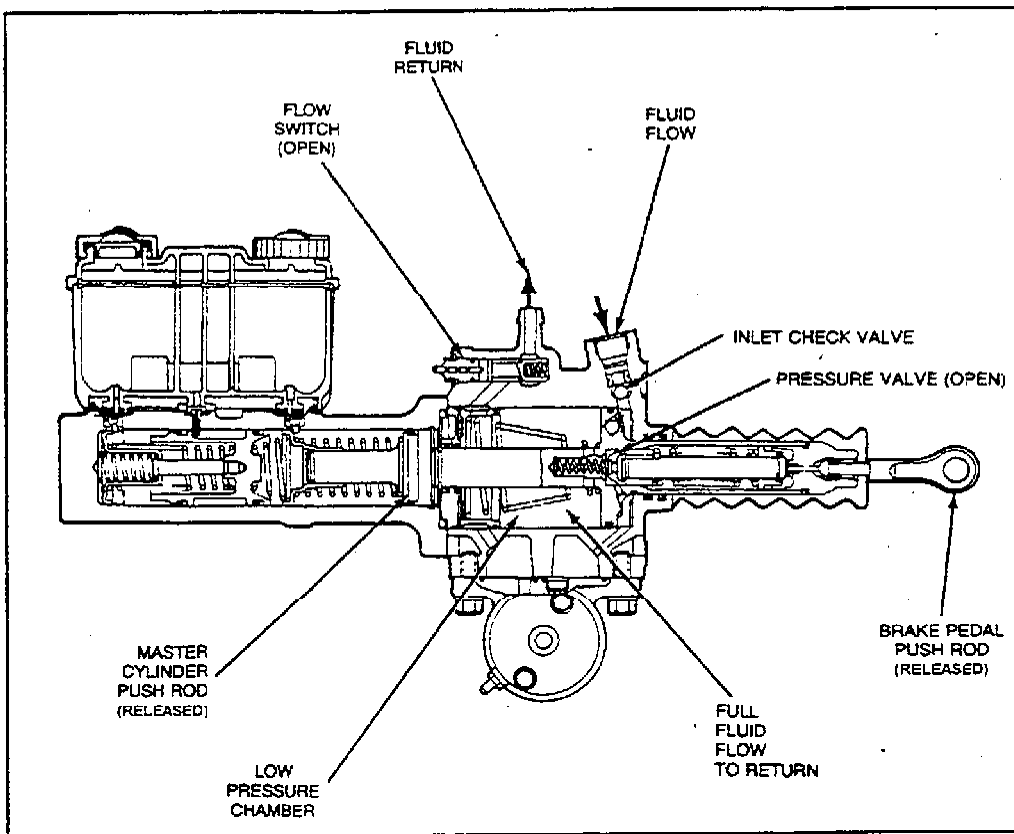


Fig. 7-6. Hydro-Max - Brakes Released

(2) Fluid passing out of the booster unit holds the flow switch open. The purpose of the flow switch is to activate the electric pump when the flow of hydraulic fluid stops, thereby providing the emergency power-assist function.

(3) No pressure is applied to the power piston and the master cylinder rod is at rest.

(4) No action takes place in the master cylinder and no brake application occurs.

c. Operation - Brakes Applied. Figure 7-7 shown illustrates the Hydro-Max brake booster with the brakes applied. It operates as follows:

(1) Flow pressure from the power steering or brake pump (located elsewhere in the engine compartment) holds the Hydro-Max booster inlet check valve open.

(2) As the brake pedal is applied, the input rod (brake pedal push rod) travels forward, which causes the pressure valve to partially close. When open, the pressure valve allows fluid to flow through the power piston. As it closes, pressure on the piston rises, creating the modulated power-assist effect.

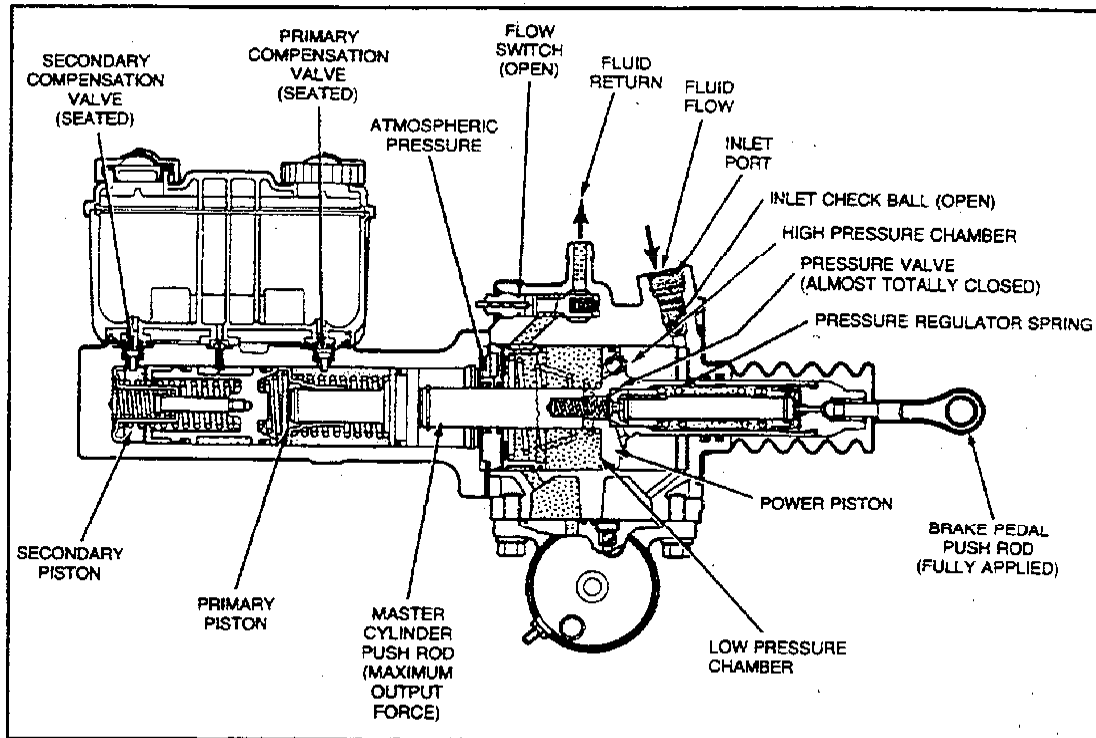


Fig. 7-7. Hydro-Max - Brakes Applied

(3) Pressure to the power piston is high during brake application, but the pressure valve never completely closes, allowing fluid to continue circulating even during sustained hard brake application.

(4) As the master cylinder push rod moves further into the master cylinder, brake fluid is pushed through the brake lines to the wheel cylinders, as in any

other hydraulic brake system. Again, the brake fluid system is separate from the power-assist fluid system, and their respective fluids never mix in a properly functioning brake system. Since brake fluid continues to circulate at all times, even when the brakes are applied, fluid leaving the booster unit via the fluid return port continues to hold the flow switch open.

(5) In the brake master cylinder, the primary and secondary actuator pistons are moved past their respective compensating valves, and both primary and secondary systems are pressurized, actuating the brakes at the wheels.

d. Reserve Power System. The Hydro-Max booster system provides virtually unlimited availability of reserve power, as long as the vehicle's battery or alternator is operating. This reserve power is supplied by the electric pump located at the bottom of the booster unit. This system automatically and immediately reacts upon brake application whenever the power steering fluid flow is interrupted. Figure 7-8 illustrates the reserve power system, which operates as follows:

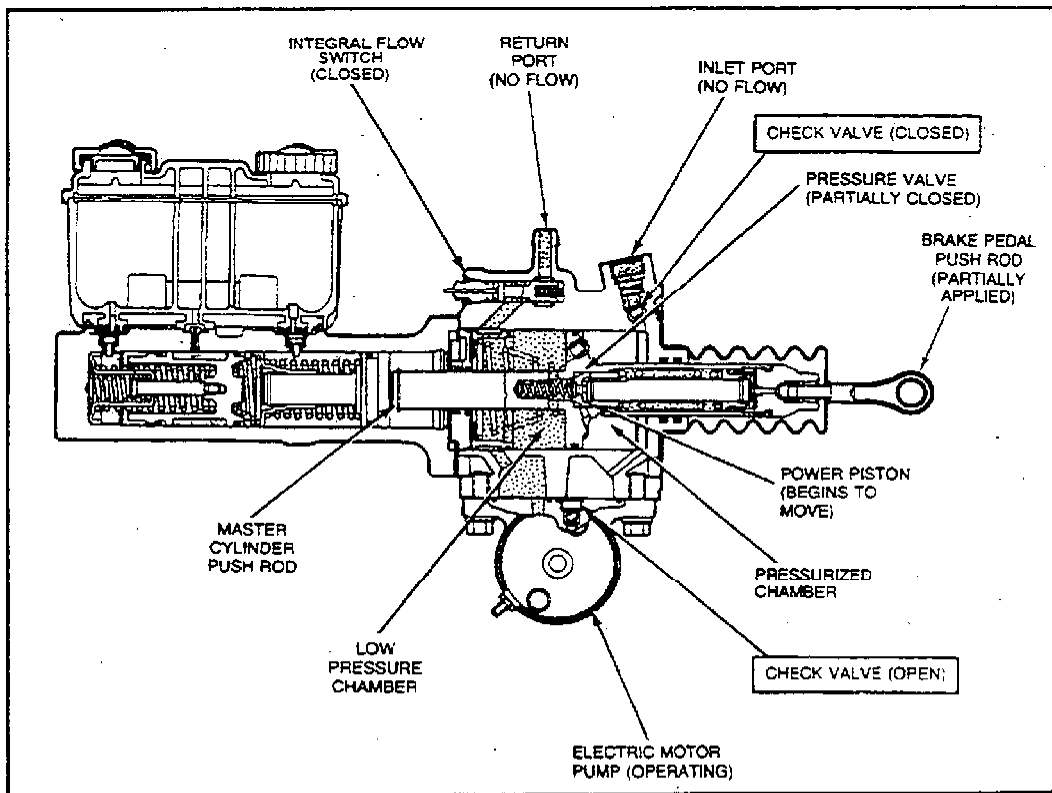


Fig. 7-8. Hydro-Max - Reserve Electric Motor Operation

(1) The fluid flow to the Hydro-Max booster will stop with engine failure, power steering or brake pump failure, belt failure, or ruptured lines from the power steering or brake pump.

(2) Without fluid flow into the Hydro-Max booster, the fluid flow out of the booster stops. When the flow stops, the flow switch on the return port closes.

(3) The electric motor pump receives its power from the reserve system relay, which is controlled by two switches.

(a) First, power to the coil of the reserve system relay is controlled by a switch that closes every time the brake foot pedal is depressed.

(b) Second, the ground path for the coil of the relay is controlled by the Hydro-Max booster flow switch, which is normally held open by circulating fluid. When this switch is closed, as described in paragraph d.(2) above, a ground path is completed for the relay coil. When the flow switch is closed and the brake pedal is depressed, the electric motor pump located at the bottom of the Hydro-Max booster unit receives power and the reserve system begins to function.

(4) During this reserve power mode, the fluid in the booster and the electric pump is, retained within the booster by a check valve at the inlet port. The check valve prevents fluid from being forced back through the supply line.

(5) The electric pump circulates fluid through interconnected ports by drawing fluid from the low pressure chamber and pumping it into the high pressure chamber.

(6) The electric motor pump supplies fluid at a somewhat lower. pressure for power braking assist. Therefore, increased pedal effort is required to stop the vehicle. The vehicle should be driven with extreme caution, and only at low speed. The reserve power-assist function is an emergency feature only, and must not be treated as a reliable, fully functional brake system.

(7) In the reserve power mode, a dash-mounted indicator lamp marked "BRK ELEC MTR" will illuminate and the buzzer (if so equipped) will sound for the period that the electric motor pump is operating.

(8) Operation of the brake master cylinder is the same as previously described for normal operation, but once again, power-assist is significantly reduced while operating in failure mode on the reserve power system.

e. Complete Boost Malfunction - Manual Brake Application. In the event that complete loss of all power-assist occurs during vehicle operation, it is still possible to bring the vehicle to a controlled stop by the push-through manual application of the brakes.

(1) The driver must apply heavy foot pressure to the brake pedal to achieve an initial braking effect. When the vehicle begins to slow, it will be more difficult than normal to modulate the brake pedal pressure for well controlled deceleration. However, by maintaining heavy foot pressure, with only slight changes in pressure when responding to deceleration feedback, an experienced driver can bring the vehicle to a relatively smooth stop.

(2) With this total failure of all power-assist, brake control is too poor for even low speed operation. The vehicle should not be driven except for emergency removal from the roadway. Even then, it should be treated as if it had no brakes at all.

(3) Operation of the master cylinder is as described previously for normal operation, except that upon loss of both the normal power-assist and the electric pump power-assist, the driver's ability to actuate the master cylinder by manual push-through is next to nonexistent, and the vehicle must be considered disabled.

8. COMPONENT PARTS (INTEGRAL HYDRO-MAX BRAKE SYSTEM). The component parts of the Hydro-Max brake system are essentially the same as described in paragraph 4.a.

9. HYDRO-MAX BRAKE AND STEERING SYSTEM FLUIDS. The brake master cylinder fluid and power steering/Hydro-Max fluid are the same as discussed for Hydro-Boost systems in paragraph 5, on page 7-8. Again, they are separate systems that use different fluids.

10. INSPECTION PROCEDURES.

a. Preliminary Inspection. The preliminary visual inspection of the Hydro-Max brake system is the same as outlined in paragraph 6.

b. Basic Functional Inspection. Check the brake and Hydro-Max systems as follows to determine if they function properly (Section 26453 VC).

(1) Basic Hydro-Max Test. With the parking brake released, the engine off, and the ignition switch in the "on" position, depress and hold the brake pedal with light pressure (15-25 lbs.). The electric motor pump should run, the brake electric motor warning lamp should be illuminated and the warning buzzer (if so equipped) should sound. If the Hydro-Max reserve system is operating properly, the pedal should not be difficult to apply, although there

may be a slight delay in power-assist while the electric pump builds initial pressure.

(2) Brake Hydraulic and Hydro-Max Leak Test. Start the engine, push the brake pedal several times, and release application pressure. There should be no warning signals and the electric motor pump should not run. Apply the brakes with heavy pressure (100-125 lbs.) and hold. The brake pedal should be considerably easier to apply and hold under this full power-assist condition. **(Caution - do not hold the brake pedal at heavy pressure for more than five seconds at a time.)**

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